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Continuous reaction as a measure of attention

Baltimore, Md.

1930

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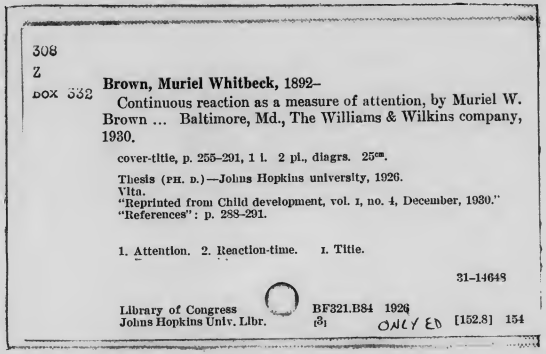

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CONTINUOUS REACTION AS A MEASURE OF ATTENTION

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BY
MURIEL W. BROWN

A DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
1926

BALTIMORE, MARYLAND
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Continuous Reaction as a Measure of Attention

MURIEL W. BROWN

THE PROBLEM

ABOUT six years ago, the present writer conducted a simple word learning experiment with a small group of children ranging in age from two and a half to four years. The task, in this instance, was to learn to recognize a number of printed words by associating them with toy objects which they represented.

At the close of the investigation we found marked individual differences in achievement. We also discovered that these individual differences did not correlate highly with intelligence as measured by the Stanford Binet I.Q. Some relatively dull youngsters with a certain placidity of temperament accomplished more, under the given learning conditions, than other, brighter, children who seemed unable to focus upon the problem for longer than a few seconds at a time. This tendency to distractibility was more marked with the younger subjects but appeared at all chronological age levels. We further noted that wherever this inattentive behavior appeared it had certain fairly well defined characteristics. Movements were mercurial,—particularly eye movements. There was marked diffuseness of energy output, with little evidence of control. Response to the test situation seemed to be, not integrated effort under the direction of a persistent idea, but rather, a series of fairly discrete reactions to an environmental kaleidoscope of stimulus patterns.

These observations raised a number of interesting questions in regard to the nature of attention. With this group of children, physical, intellectual and emotional factors seemed to be nicely integrated in the attentive states. What interfered with the coordinating of processes in the inattentive states? Is inability to control attention an organic, an emotional, or an intellectual defect? Does the power to attend develop gradually in small children with measurable increments between chronological age levels? Can attention be measured at all?

The following study is an attempt to explore a small corner of this very large and interesting field. It aims to deal with three aspects of the problem:

1. The measurement of attention
2. Acquisition of control of attention
3. Individual differences in attentivity

An experimental situation has been devised which rules out, as far as possible, known conditioning factors. Success depends primarily upon attention to the task,—a simple repeti-

tive process. The subjects are young children with no previous experience in this sort of thing. The set-up is a modification of the continuous reaction apparatus.

REVIEW OF THE LITERATURE

It has been somewhat difficult to relate this experiment to the older psychological work on attention, first, because it began as a frank exploration, planned to yield data which would suggest, rather than test, hypotheses; second, because of various confusions in terms. A review of the literature discloses so many definitions of attention that one is lead to wonder whether James could possibly have intended to include psychologists when he said "Every one knows what attention is."

The earlier writers (pre-18th century) regarded attention, in the main, as "an unanalyzable attribute of the soul—evidence of the independent activity of the mental principle." (3, p. 86). The majority of English empiricists (particularly Hume, Hartley, and Spencer) ignored it, perhaps, as James suggests, because it could not be treated as a pure product of experience. The Germans before Herbart "explicitly treated of it," but "either as a faculty or as a resultant." (35 p. 402). The literature of the late 19th century bristles with theories which Baldwin (3), p. 86) classifies as:

1. The affective.
   "Attention is an intellectual monoideism accompanied by spontaneous or artificial adaptation of the individual." There are two kinds, spontaneous and voluntary. Spontaneous attention is the rudimentary form and is the outcome of the natural impulses and desires; its essential elements are the motor processes. Voluntary attention does not differ in kind, but is later in the order of development, and "depends upon the emotions or impulses acquired by education." (72, p. 6.)
2. The "psychical energy" and "original activity" theories, (Lotz, Wundt, Stumpf, Ward, Ladd, etc.).
   Attention is defined in terms of degrees of consciousness. "We are, at the moment more conscious of some objects than of others, and it is the objects of which we are most conscious to which we are said to attend, or which are said to be 'clear'." (42, p. 597.)
3. The conative and motor theories, (Bain, Lange, Munsterberg, Stout, Baldwin).
   "That the ideational preparation itself is a consequence of muscular adjustment, so that the latter may be called the essence of the attention process throughout." (35, p. 444.)
4. The "intensity" and "reinforcement" theories, (Condillac, G. E. Muller, Bradley).
   These assume central sensory reinforcement of peripherally excited or centrally prepared sensations or ideas. (40, p. 444.)
5. The "inhibition" theory, (Ferrier, Alexander, etc.).
   "The physiological or psychological principle underlying every act of attention is inhibition in order to concentrate,—the shutting out of irrelevant matter in order to examine some central point." (2, p. 295.)
   "The changes which conscious contents undergo in one state of attention, and the motor phenomena which follow in its train admit of two interpretations, one of which accredits attention with functions both of reinforcement and inhibition, while the other attempts to explain all the facts in terms of inhibition alone." (40, p. 444.)

These brief quotations will suffice to give a bird's-eye view of the range of thought upon the subject under discussion. It is clear, as Külpe points out, that psychology has "confused in its idea of attention, three very different notions: that of a faculty, the operation of which produces certain changes in the mental life; that of an activity, the activity of remarking, noticing, observing,—always directed upon some definite content which is the occasion of its exercise; and that of a state in which we continue for a longer or a shorter time, unaffected by changes in the content of our consciousness." (41, p. 42).

"Contemporary psychologists," writes H. M. Johnson, "make use of a single term 'attention' to designate two variables, indifferently. One of these variables is the degree of consciousness, or the clearness of content; the other is the degree of the sensory and motor adjustment of the organism with respect to a particular stimulus." (37, p. 601). Since Woodrow (92), in 1916, argues at length for a "faculty" of attention, we may doubt whether the number of issues has been so far reduced as Johnson supposes. It seems to be true, however, that the concepts to which he refers have a general acceptance, and that as he further states, "two representative authors," Münsterberg and Dunlap are able to combine the two views in a theory of attention which specifically postulates that "the 'degree to which one is conscious,' or the 'clearness and vividness' of content, is determined by the degree of adjustment for reception and response; the latter being perhaps theoretically expressible as some function of the number of different pathways which combine in producing the appropriate response." (37, p. 604.) In other words, integration and attention,—consciousness, too, if you like,— are the same thing. It is surprising—and interesting,—to see how much of the old obscurity vanishes if the earlier theorists are translated into the language of modern scientific psychology.

The specific problems attacked in experimental studies of attention Baldwin (3) groups under the following heads: (1) Fluctuation of attention; (2) complication; (3) range of attention; (4) distraction of attention; (5) influence of attention on the estimation of time intervals; (6) reading time experiments; (7) attention and concomitant processes, physiological and psychological; and (8) the effects of attention.

The experimental work done between 1874 and 1908 has been admirably reviewed by L. R. Geissler (29), with special reference to method. He distinguishes between (1) the general means of inducing variations of attention, and (2) the special means employed for the measurement of these variations. Under (1) he divides procedures into the "single-task," or distraction method, and the "double-task," or the method of simultaneous activities. The "single-task" method was first used in 1874 by Wundt (93) and Obersteiner (60) who attempted to measure attention by means of reaction time using auditory, cutaneous and visual distractors. Distractors of many kinds have been used since then in a wide variety of experimental situations.

The "double-task" method was first employed by Loeb in 1886, to find out whether muscular activity could be used as a measure of mental activity. His work was later extended to include the correlation of the muscular strength of the hand with many different mental activities, such as visual and auditory perception, mental addition and multiplication, reading, writing and repeating poetry. In this connection the names of Münsterberg (56, 57, 58, 59) W. G. Smith (76), Drew (17), Binet (4), and Henri (34) should be mentioned, also those of McDougall (50, 51), and, particularly, Wirth (89). Experiments with both methods show that with different people the same distractions have different effects but the results are unreliable, depending largely upon the effectiveness of the distraction material as such. Distraction material may be ineffective, (1) because of lack of continuity, which permits the other task to rise, at moments, to the focus; (2) because of adaptation; (3) because of the improbability of getting distraction material which affects all normal subjects in the same way. (29, p. 492.)

The methods proposed for, or employed in, the measurement of attention, Geissler divides into six groups. "The first five may be classified as methods of expression. According to these, degrees of attention may express themselves in changes of, (1) peripheral vision; (2) muscular strength; (3) liminal and differential sensitivity; (4) reaction time; (5) accuracy of work. The sixth method may be likened to the method of impression. By a series of graded distractors, degrees of attention are to be induced in the observer, and he is afterwards to report which degree he experienced." (29, p. 492.)

Method 5 is essentially the method of the present experiment from the point of view of treatment of data, and, therefore, has a special interest here. This method "seeks to find an expression of the degree of attention in the quality and quantity of the work performed in a given time." Jodl (36, p. 84–85) says of it, "It is obvious that attention cannot be measured directly. However, its degrees may be determined indirectly by reference to its effects. These effects consist, in every task which does not have the character of an involuntary movement, in the avoidance of errors and mistakes and in the quickness of the execution." Stern (77, p. 84) also holds that "the quality and quantity of a task performed under normal conditions could be used as a measure of the attention energy."

Friedrich (26) first suggested a modification of this method in 1883 "It is tempting," he writes, "to fix definitely the somewhat unsettled concept of attention by making it proportional to the measure of precision, i.e., to the reciprocal value of the mean error, so that a small mean error corresponds to a high degree of attention, and conversely a large mean error to a low attention,—since the characteristic phase of attention consists rather in the large variations of the physiological times within the same experimental series." (26, p. 73.) He warns, however, that "only in cases of the simplest mental processes, which besides should be as homogeneous as possible, and little subject to practice, may one assume that the mean error is mainly dependent upon the degree of attention. With more complex mental processes not only does practice play a considerable part in the fluctuations of the individual experiments, but, in certain cases, the cause of great variations may lie in the mental processes themselves." Oehrn (62) had 10 subjects count letters, look for certain letters, read proof, etc., and "made a wide application of the mean variation as the 'dynamometer of the attention'." (26) He found significant individual differences in variability and, particularly, differences in the kind and amount of attention given to the various tasks. Henri criticizes Oehrn's conclusions on the ground that factors like fatigue and practice were not eliminated, and certainly must have influenced the mean variations. Peters (63) found a close connection between the magnitude of the mean variation in determinations of liminal sensitivity and the degree of attention under which he had established the limen, "but assumed that" practice had a slight but distinct effect upon the results. Geissler suggests that the mean variation can best be used as a check upon conclusions drawn from other techniques.

Since 1908, experiments in the field of attention have touched upon all of the eight main problems outlined by Baldwin, tending of late years to center about either the clearness or the muscular adaptation hypothesis. Geissler (29) reports, on the strength of a study of fluctuations of attention to cutaneous stimuli, that "under good conditions, attention focused on liminal and subliminal sensations remains approximately constant for at least two or three minutes, and then gradually fades," (through adaptation). In 1909, he tested "the assumed parallelism of the expression methods" by correlating "the accuracy and quantity of work performed with the muscular rigidity or motor inhibition which is said to become the more pronounced the more attention is concentrated." (29, p. 503). He found "a very close parallelism . . . to exist between introspectively distinguishable variations of attention and corresponding differences in the precision of work performed at these levels under the condition that the estimation of degrees of attention was made in terms of clearness and that the work itself was not influenced by anything else but change of attention." (29, p. 529.)

Experiments for 1910 have to do particularly with Wirth's (89) method of measuring distribution of attention,—the method of liminal differences for brightness in different parts of the visual field under varying distributions of attention. Lipps (44) repeated Wirth's experiments and in general, confirmed his results, finding that the central and lower portions of the field were materially favored. The influence of attention in this situation is not clear, according to Pillsbury. Whipple (88) tested the mind-training theory proposed by Miss Aiken (1) and found but a negligible improvement in visual memory span for letters or objects, although his subjects were trained by 100–200 exposures. Dunlap (18), 1910, worked on the complication experiment and found three general methods of judging the posi-

tion of the moving pointer at the moment of a discrete stimulus, each of which produced a characteristic quality and quantity of error. Billings and Shepard (5), 1910, studied change of heart rate with attention and decided that the primary effect was in the respiration rate, which in turn affected the heart rate. There is frequently restricted breathing with sensory attention, they assert, which decreases the heart rate; with central attention there is little change in breathing, but a slight tendency to increase.

McComas (47), 1911, made an interesting study of types of attention, using various kinds of material in a field exposed by means of a tachistoscope. He found, in general, two types of attentional activity,—the broad and the narrow spanned. Subjects who were broad for visual were also broad for auditory span. Two other types were discovered—the alert, active, quickly controlled, and the sluggish, the former being broad-spanned. Intercorrelation of the data showed that the ability to concentrate and inhibit did not appear to be closely related to any other marked traits of attention. Prager (64) worked on the relation between defects of attention and control of association and found that disturbances of functions in the two fields went hand in hand. In a study of the effect of alcohol on attention, Busch found a narrowing of the field after 30 cc. of alcohol, (9).

The relation between attention and breathing was reexamined by Suter (79), 1912, who points out a difference between strain of attention and concentration. Feilgenhauer (22) in this same year worked on rate of change of attention with disparate stimuli (visual and auditory). He found "the smallest active step of attention to be 300 sigma, with little change of limits for different kinds of stimulation." He also discovered that the shifting of attention from stimulus to stimulus was smooth if stimuli were in the same realm, otherwise not. Rate of change, which, he thought, depended on the personality of the observers, could not be voluntarily accelerated, although it could be voluntarily slowed. Rate of change did not appear to be affected either by position of optical stimulation, direction of movement, or increase of stimulation.

Five papers in 1913 dealt with direction of attention. Flügel, (24, 25), used figures drawn in double perspective, and decided that direction of attention was the prime factor in reversal, and that local fatigue was not of importance. Billings (6) measured the duration of attention to supra liminal stimuli and found the maximum much smaller than the so-called attention wave. His 21 subjects gave a median of 1.69 seconds for duration of attention to a small object. Pillsbury (66) points out that if each recorded change in this case is thought of as two waves,—change, and awareness of change,—the resultant value corresponds approximately to Sherrington's refractory period of the reflex, and also to "a number of times in different mental operations that have been referred to the attention wave, or that probably have approximately the same conditions in the nervous systems." (66, p. 169.)

Martin, Paul and Welles (46), 1914, tested the validity of the use of the sensory threshold as an index of the general state of the nervous system, comparing the threshold of the winking reflex, secured by faradic stimulation of a selected spot on the lower lid, with the sensory threshold for the same spot on the lid. Results showed that the reflex threshold tended to vary from its mean value less than the sensory threshold. The fact that "direction of divergence" was nearly always the same for the two types of limen was taken to mean that the attention, under the conditions of these experiments, manifested itself as a function of the condition of the higher brain centres. The authors conclude that the value of the sensory threshold depends on the state of the higher centres and that the threshold may justly be used as an indicator of such state. Woodrow (90), 1914, published a monograph on the measurement of attention which he followed with a paper in 1915 (91). He deals particularly with reaction to surfaces with sharp outlines, with and without the distraction of a warning signal occurring at irregular intervals before the stimulus. The conclusion seems to be that irregular intervals of this nature increase reaction time, (presumably because they do not coincide with the attention wave), but have less effect when the outline of the stimulus is clear.

In 1916, Woodrow (92) applied his method of distraction by means of irregular preparatory intervals to a study of the reactions of 12 subjects to touch, sound and light stimuli. His results led him to conclude that the mode of stimulus is a condition of attention. Marked individual differences were found but these, although differing in magnitude for the several cases, were found to be relatively the same for each type of stimulus. Woodrow concludes that "the degree of attention of any individual is conditioned in part by certain general conditions which remain constant while the type of mental process concerned is varied," and that "it is to these general conditions alone, are due the individual differences in degree of attention found in the present investigation," (92, p. 317). Curtis and Foster (12), also in 1916, studied the effect of changes in intensity and size upon the clearness of a Greek cross, and found that change in size has no effect. Clark (11), 1916, conducted an experiment in visual imagery and attention from which he concluded that (1) "changes in the clearness of the image correspond, to an appreciable extent, to the movements of the eyes; that ocular movement is more likely to occur in secondary attention than in primary or derived primary attention; and that characteristic ocular movements, and possibly general motor attitudes seem to be transferred from visual perception to visual imagery. (2 subjects.)

Morgan (54, 55), 1917, reëxamined the problem of attention during distraction and found that although 13 of his 21 subjects suffered a brief diminution in capacity at the beginning of distraction all but 4 finally gained. The measurement of incidental movements showed that increased capacity was the result of greatly increased force.

McQueen (52), 1917, found no correlation between the ability to distrib-

ute in one task and in another. He used the correlation method in the treatment of data obtained from 40 school children. He concludes, from his study that the capacity to distribute is specific, and adds that he found a low correlation between success in distribution and teachers' estimate of intelligence. The coefficient of correlation is highest for tests requiring concentration, and is negative for motor tests.

McComas (48), 1917, publishes an account of a new apparatus for recording continuous discrimination reactions, an apparatus very like the one used in connection with the present experiment. McComas' subjects reacted to four differently colored lights by pressing different keys. The lights appeared upon an exposure screen and the instant one colored light was extinguished another appeared. The order of appearance was miscellaneous and not repeated for 60 exposures. The rate of exposure was controlled by the subject and the records were taken off on a smoked drum. "A marker in circuit with the armature of the clock registered each correct reaction, and a marker in circuit with the reaction keys scored all reactions made."

Lobsein (45), 1919, gave Münsterberg's motormen's test to 12 children as a measure of attention and obtained a high correlation (r = .84) between intelligence and the test results. His criterion of intelligence was the ability to meet new demands, (made by tests of his own devising), quickly and accurately. He found, also, an inverse relation between extent and efficiency of attention.

Liddell (43), 1920, tested Ferree's theory that attention waves are due to adaptation of the part of the retina stimulated and got no relation between eye-movement and fluctuations of attention. Bowman (7), 1920, in a study of size vs. intensity as a determinant of attention found that "the left hand position is the more favored."

Fernberger (23), 1921, stresses the importance of range of visual apprehension as distinguished from range of attention. He points out that the statistical limen is a more reliable and more readily determined measure of the latter than any of the classical methods of getting span, since "in the range of apprehension one is interested in determining the number of objects the correct apprehension of which has a probability of 0.5." He finds that the observed relative frequencies of correct judgments follow a continuous function of ogive form, and that the individual limens in his experiment ranged from 6 to over 11 stimulus objects. (dots.)

Dallenbach (13, 14), 1922, compares position with intensity as a determinant of clearness and finds that "the left hand position and the position above have the attentional advantage, and that the most advantageous position of all is the position to the left and below the point of fixation.

McComas (49), 1922, used his continuous discrimination apparatus as a measure of attention in an experiment with 11 adult subjects. In the treatment of the results he considers particularly the relation between right and wrong reactions, assuming that "the

increase of the wrong reactions is an indication that the subject is relying less upon careful discrimination and choice of reactions and more upon chance, (which thus) becomes the prominent factor in the situation." (49, p. 7.) On the strength of this assumption, all of the wrong reactions were regarded as chance reactions, with the probability that 75 per cent of the chance reactions were wrong. This, according to McComas, left 25 per cent of chance reactions which were right. He, therefore, derived his scores by subtracting one-third of the number of wrong reactions from the total number of rights. During the past winter, the present writer has had many opportunities to note the great variety of circumstances which led, in the case of her five year old subjects, to the final pressing of the wrong key. In the light of the children's behavior, McComas' assumption of the nature of error seems somewhat unsatisfactory, and probably lessens the significance of his conclusions. His subjects reacted continuously for periods of ten minutes, and the scores show "marked differences in speed and accuracy of reaction and in the temporal variations in these factors." Reaction times were taken.

Dockeray (16), 1922, reports experiments with the sounder test, which he recommends highly as a test to determine individual differences in ability to overcome distraction. H. M. Wells, (87), 1922, notes that during a "choice" reaction there is a fall in resistance, indicated by the psychogalvanic reflex.

Griffiths and Gordon (31), 1924, go again into the question of the relation between Traube-Hering waves and attention rhythms and find a slight correspondence, which they attribute to the vasomotor changes accompanying attention and the motor responses associated rather than to the Traube-Hering rhythms themselves. Oehrn (62), 1924, repeated the classical "range of attention" experiment, using psychophysical procedure, and concluded that practice tended to increase the value of the threshold.

H. M. Johnson, (37), 1925, considers the "clearness" experiments of Cassel and Dallenbach (10), and shows by further statistical treatment of the original data that "the precision with which any particular value of clearness, Y, can be inferred from the corresponding reaction time, X, is but 3 per cent greater than the precision based on a mere guess from the average My—in other words" there is no proof here (as the authors claim) that the reaction time is determined chiefly, if not entirely, by the degree of adjustment for reception and response.

For a resumé of the work done between 1925 and 1928, the reader is referred to Dallenbach (15). Dallenbach classifies the studies published during these three years in four groups, as follows:

1. Those concerned with the definition and ultimate nature of attention.
2. Those dealing with some special aspect of the subject, such as range, fluctuation, etc.
3. Those that treat of attention in relation to some other phenomena.
4. Those that are technological.

Nothing reported under 1 is of special interest in connection with this paper

except possibly a bit of nursery school research (Bertrand) in which an attempt is made to differentiate between spontaneous and voluntary attention in 36 children ranging in age from two years two months to six years. The author of this investigation finds that the length of time his children attended to a game varied greatly for different days. He reports an age and sex difference in the duration of this type of attention, and also finds that the means vary on different days of the week and on the days following holidays. One suspects that the measurements in these situations were affected by a good many other factors besides attention however defined.

With respect to 2,—special aspects of attention,—Dallenbach finds a wide range of studies of varying interest and importance. There appears to be a marked tendency among experimenters to agree that "the question of range is not a proper one to ask regarding attention. *The attentive consciousness is an integrated whole;* and as such the range of attention is unity." It seems also to be agreed by most writers that so-called fluctuation of attention is a question of limen. Dallenbach and Johnson continue their debate on the problem of measurement, Dallenbach stressing again his thought that by a proper treatment of reaction times it may be possible to discover the relations existing between clearness and reaction. Sterzinger (78) reports the results of a study of distribution of attention. His subjects added continuously while listening to the reading of a short story. The author concludes that generalization from this type of experience is risky, since it is difficult to tell under such conditions whether one is dealing with simultaneous or with rapidly shifting attention.

Several papers during this period dealt with the relation of attention to other phenomena, Dallenbach's third classification. Dallenbach describes an "attentional learning board" devised by Roberts and Farnsworth. With this apparatus, the rapidity with which the problem is solved depends upon the subject's attention to details.

Under 4, we find some discussion of tests of attention. Sterzinger (78) points out that such test results are significant only in so far as they test special abilities.

A paper by Skawran (75), is interesting in that it makes a more theoretical attack upon the problem of attention, and contains the statement that "all volitional decisions (as in choice reactions) are to be attributed, in greater or less degree, to feelings and strain sensations."

Verwoerd (84) in 1928, published a paper on the testing of distribution of attention. His subjects reacted to the flashing of stimulus lights by pressing corresponding telegraph keys. He found large individual differences in general efficiency and evenness, but concluded that the two were not correlated. The nature of the set-up makes a detailed analysis of this relationship difficult if not impossible.

In 1929 we find several studies of some importance, a number of them coming from German laboratories. Kindler (39) investigates training of attention, using the Bourdon test for typing, adding, etc., and getting his subjects to report on introspections. He concludes that training in certain situations is possible but that such training is influenced by a variety of conditioning factors.

Enke (21) studies the splitting of attention in relation to constitutional type, and finds that results are not influenced by differences in the ages of the subjects. He infers from this that age does not influence the constitutional type. With this investigation, Enke enters a fascinating field and one but little explored. Studies of this kind are quite likely, eventually, to give us a technique for diagnosing in young children incipient psychotic trends.

Wallon, in France (85) investigates the psycho-physical causes of inattention in children. The author avoids the use of the term attention as ambiguous but finds that "nearly all the causes leading to *in*attention are correlated with motor disorders."

Perhaps, after all, this negative approach gives us one of our best clues to the real nature of attention. The long attempt to subtract an attentive process from other mental processes has obviously failed. On the other hand all of the experimental work done, even those investigations based on the older hypotheses, seems to strengthen the major premise of modern scientific psychology—the concept of an integrated organism reacting to stimulation as a whole. One now finds the terms "attention," "dominant pattern" and "integration" all used in the literature with essentially the same meaning to describe this totality of response. We pick up the thread in our present study by making this our working definition.

ORGANIZATION OF THE EXPERIMENT

Re-statement of objectives

The general purpose of this investigation has already been stated: We aimed to experiment with the problem of measurement, to study the question of control, and to analyze certain individual differences in attention to a given stimulus—response situation. We defined attention as the integration of all relevant processes, physiological and psychological, in a total response pattern. Proceeding from this definition, we made the fundamental assumption that a measure of efficiency in performing a simple motor act is also a measure of attention.

Method of approach

The next step was to find a response situation in which learning, fatigue and distraction were essentially non-operative factors. The response must be selective, since it is this element of selectivity which differentiates attentive behavior from the predominantly reflexive type. The familiar continuous reaction experiment seemed admirably suited to our purpose in that it required a selective reaction; the learning involved was extremely simple; and certainty and accuracy of response could be measured with relative ease.

Apparatus

The basic set-up chosen for this experiment was Dunlap's LVN apparatus described elsewhere in detail by the author, (20). This requires the subject "to react to the flashing of a row of miniature lamps by a specific movement in reference to each lamp in the row." (20). This "specific

movement" is the pressing of one of a row of telegraph keys corresponding to the row of lights.

The equipment consists of three main parts,—the switchboard with the lights and the telegraph keys, the mechanism which controls the flashes, and the kymograph which records both stimuli and responses.

Our switchboard was unique. In the original experiments this bit of the apparatus had for stimulus lights 4 small incandescent bulbs arranged in a horizontal row. In order to make the experience intrinsically interesting to our young subjects we placed these bulbs behind the eyes of two tin cats (identical twins) and fastened these cats side by side in such a way that the bulbs were equidistant and in a horizontal row. The cats were a neutral gray and were mounted in a box lined with dark gray flannel 47 x 31 cm. on the side. (See plates 1 and 2.) Each cat was 15 cm. in height, and each eye 2½ cm. in diameter. The eyes, as they flashed, were a glowing green with small, round, red pupils. The children sat upon a stool facing the lights in such a position that the natural point of visual fixation was a spot (not marked) on the back of the box half way between the two middle lights. There was nothing within the range of vision that could compete with the light flashes in stimulus value.

The side of the box upon which the cats were mounted was set upon a stage 25 cm. above the table top on which we built up this part of the apparatus. Below the stage we lined up the 4 telegraph keys in such a way that each key was 28 cm. below and in a line with one of the eyes. These keys were fixed in a vertical position so that to tap them the child pushed forward instead of down. Upon the table top, in front of the row of keys, we put a low platform 5 cm. high covered with the same gray flannel which lined the box. On this the children rested their forearms while reacting with the fingers. On the hand rest, under the flannel, in front of each pair of keys we fastened two little wooden cylinders, about where the hands would lie. These served the double purpose of supporting the palms and of keeping the fingers from resting too near the keys.

The flashing of the lights in the eyes of the cats was controlled by a machine made in the Hopkins Laboratories according to Dunlap's specifications. Dunlap's description (20) follows:

> "(There are) four contact wheels, cut from brass, with bakelite filling between the contact lands. Spring brushes resting on the peripheries of these wheels provide reliable contacts and breaks. These contact wheels are rotated by four worm wheels on their respective shafts, all four worm wheels being driven from a single worm shaft on which are cut two worms, two worm wheels being driven from each worm. The worm wheels have respectively 101, 103, 105 and 107 teeth so that although the series represented by one wheel repeats itself after a certain number of minutes, the four series are steadily changing with relation to each other, and the four series return to their original relation only after 343, 824, and 705 rotations of the worm shaft. . . . . The stimuli may occur singly, or two, three or four may occur simultaneously. The lands of the contact wheels are of equal angular measure, but distributed on each wheel in a carefully planned irregularity. The length of time each stimulus lasts, (the length of time each lamp remains lighted), and the average interval between stimuli, in each of the four series is determined by the speed of the rotation of the worm-shaft." (20, p.

THE CATS, THE KEYS, AND THE KYMOGRAPH

INTENTIONAL SECOND EXPOSURE

movement" is the pressing of one of a row of telegraph keys corresponding to the row of lights.

The equipment consists of three main parts,—the switchboard with the lights and the telegraph keys, the mechanism which controls the flashes, and the kymograph which records both stimuli and responses.

Our switchboard was unique. In the original experiments this bit of the apparatus had for stimulus lights 4 small incandescent bulbs arranged in a horizontal row. In order to make the experience intrinsically interesting to our young subjects we placed these bulbs behind the eyes of two tin cats (identical twins) and fastened these cats side by side in such a way that the bulbs were equidistant and in a horizontal row. The cats were a neutral gray and were mounted in a box lined with dark gray flannel 47 x 31 cm. on the side. (See plates 1 and 2.) Each cat was 15 cm. in height, and each eye $2\frac{1}{2}$ cm. in diameter. The eyes, as they flashed, were a glowing green with small, round, red pupils. The children sat upon a stool facing the lights in such a position that the natural point of visual fixation was a spot (not marked) on the back of the box halfway between the two middle lights. There was nothing within the range of vision that could compete with the light flashes in stimulus value.

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THE CATS, THE KEYS, AND THE KYMOGRAPH

CHRISTINE APPROXIMATELY IN THE REACTING POSITION

137). The worm shaft is driven by "a synchronous motor of a greatly improved model, so that the timing is extremely accurate."

The rate of stimulation was determined in a more or less arbitrary fashion. Several five and six year old children were tried on the apparatus before the experiment began in order to find out approximately how many flashes they could respond to in a working minute without showing signs of distress. On the basis of these observations the following rate was tentatively adopted: 4.5 flashes per key per minute, mean variation .12; average number of flashes for all keys per minute 18.05, mean variation 1.01. Each flash lasted approximately two seconds. The apparatus was set for this speed for the first 4 subjects, but this initial rate proved to be too slow. The children learned the task quickly, and, naturally, lost interest during the seemingly long waits between flashes. It happened one day toward the end of these first series that the adjustment of the motor was disturbed in such a way as to double the number of stimulations per minute. The child reacting was not disturbed, producing, on the contrary an excellent record. We, therefore, discarded the first 4 sets of records from the main series and established a standard procedure as follows: For the first three series, an initial rate of 4.5 flashes per key per minute, (m.v. .12); for series IV to X, double speed with an average of 10.4 flashes per key per minute, (m.v. .22). The duration of the short flash was approximately one second.

Stimuli and responses were registered by a kymograph of a model (designed and built in the Hopkins shop) which has 4 ink pen writings on continuous paper. This kymograph stands on the floor, on its own base. Each pen is hooked up in a circuit with one stimulus light and the corresponding response key in such a way that we obtained the following records for each separate light and key: "(1) A record of each stimulus whether reacted to or not. (2) A record of each reaction to a stimulus whether occurring before, during, or after the stimulus. (3) A record of each "wrong" reaction, each pressing of the wrong key." (20, p. 138.)

The entire apparatus was set up in a small room, 5 feet, 5 inches by 9 feet, 6 inches by 9 feet, which contained nothing else. Ventilation was by means of a window opening on an air shaft, and a door. The room was lighted by an electric bulb in the ceiling. The "Cat-box" was in a corner against a dull, buff-colored wall. Kymograph and motor were behind the reactors, and screened off. Fortunately both motor and kymograph worked with a minimum of noise.

Subjects

Our subjects were 20 white, five year old children, 12 girls and 8 boys. We limited ourselves to an age range of two months, using only those children whom we could test within the month preceding or following the fifth birthday. The difficulty of finding children of exactly the right age precluded the possibility of selection on any other basis. Public records of births, from which preliminary lists of five year olds might have been compiled, were not available to us. It was necessary, therefore, to hunt up our subjects one

by one. Most of these finally came through teachers in two public schools, through mothers in child study groups and through members of the Johns Hopkins faculty. When all other sources of supply failed to produce the right kind and number of children, we sought out populous streets and rang the door bells!

The group, as finally constituted, represented no one social level. The majority, 13, of the children were sons and daughters of business men. Of the remaining fathers, four were in professional work, one was a mechanic, and one a street railway conductor. In the remaining case, the father was dead.

TABLE 1

Descriptive data for each subject in the experimental group

Nationality of All Children: American.
Chronological Age of All Children: 5 years ±1 month.

NAME	I.Q.	MENTAL AGE	NUMBER OF CHILDREN IN FAMILY	POSITION OF THIS CHILD IN FAMILY	SCHOOL EXPERIENCE	NATURE OF FATHER'S OCCUPATION	SPECIAL INFORMATION
Ada	123	6-2	2	Older	Kindergarten	Profession	
Amy	123	6-2	3	Second	No	Profession	
Bertha	103	5-2	1		Kindergarten	Business	
Betsy	120	6-0	1		Kindergarten	Business	
Brinton	132	6-6	2	Older	No	Business	
Bruce	83	4-2	1		No	Business	
*Christine	130	6-6	1		No	Business	
Deborah	145	7-2	1		Kindergarten	Profession	Father dead, mother working
Dolly	117	5-10	5	Youngest	No	Business	
Edith	80	4-0	2	Older	No	Mechanic	
Esther	145	7-2	2	Older	No	Business	
Harold	90	4-6	2	Younger	No	Business	
Jessie	102	5-2	4	Third	No	Profession	Father dead, mother working
John	105	5-3	1		No	Business	Parents divorced
Laura	123	6-2	2	Younger	No	Business	
Martin	80	4-0	6	Fourth	No	Street car conductor	
Molly	113	5-8	3	Oldest	Kindergarten	Profession	
*Peter	116	5-10	2	Younger	No	Business	
Robert	105	5-4	4	Youngest	No	Business	
*Spencer	113	5-8	2	Younger	Kindergarten	Business	

* Jewish.

Nothing definite was known of the nature of family relationships in the homes from which our children came. In 18 cases the child appeared to be living in a normal home environment. In one case the child and her widowed mother made their home with maternal relatives, the mother working. Also in one case, the parents were divorced, —the child living with its mother. Three of the children came from a large, fashionable apartment house, two from homes of apparent poverty, the rest from nice, "average," American families. Three of the youngsters were Jewish, the rest American Gentiles. Six subjects were only children. Five were already in kindergarten. This data are summarized in table 1. The names used in this report are fictitious.

Daily program

The experiment proper was, of course, the "working" of the Cats. In order to make the children's approach to the testing situation as easy and natural as possible this "working the Cats" was not emphasized in any way but was presented to them, without particular comment, as one of the lessons in a varied school program.

Through their mothers the youngsters were invited to attend two weeks of kindergarten at the University. Although constant for each one, school time was not the same for all subjects since in most cases our schedules had to be adjusted to household routines. For the same reason it was impossible to have equal numbers in the groups. Five of our children came alone, the others in twos and threes. The testing period lasted for ten days, every effort being made to have these days consecutive. In only one case was there a significant break in the series.

The school program was carefully planned to establish rapport. The children were called for each day at the time agreed upon, brought to school in an automobile, divested of hats and wraps, and taken into the "schoolroom." This "schoolroom" was, in fact, a corner of one of the big laboratories, screened off from the rest of the room. Here a rug, three small chairs, a long low table and one or two bright posters gave a workshop atmosphere to which the children responded readily; toys and constructive materials,—colored papers, crayons, scissors, paste, etc., were kept nearby in a convenient cupboard which formed one wall of our "room."

On his first day of school, each child was given the Stanford Revision of the Binet Scale, and was allowed to make friends with the Cats. For the rest of the days of each series the schedule was about as follows:

1. Construction with paper. 30 minutes. The projects were simple,—paper lanterns, posters, calendars, etc. The children worked intently and carried home the finished objects with pride. This preliminary lesson period gave the youngsters time to adapt to the new environment, and secured a positive coöperation which, in all cases, seemed to carry over into the experimental situation.
2. Toilet
3. Experiment proper,—"Working the Cats." 10 minutes

4. Stories and games. 30 minutes
   From time to time, at this period, we introduced certain standardized performapce tests. These gave us data which will be used elsewhere in working up another aspect of the experiment. They will not be referred to again in this paper.

We were fortunate in being able to win and to hold the interest of all of the children, each one of whom protested vigorously when his two weeks of school were finally over.

Experimental procedure

The procedure outlined for the experiment proper was rigidly followed. When a child was first taken in to see the cats he was allowed to feel them, to look about the room, if he so desired, and to watch the eyes flash for a while. He was then set squarely on the stool facing the apparatus and instructed in this way:

"You see these two tin cats? Each cat has two eyes, hasn't it? And each eye shines very bright when the little light goes on inside. Now look at these buttons (pointing to the keys). There is one for each eye. Show me which one goes with this eye (pointing to the one in the extreme left). Which one goes with this eye? With this one? With this one? All right. Now, I want you to put your hands here—this finger on this button, this finger on this button (demonstrating for all four). You are to learn to press the right button as soon as you see the light in the cat's eye. Press each button just once, *hard*, all the way down, and let it right up. Now. Let's try!"

A minute of preliminary practice was given, no records being taken of this. The experimenter then explained that, after working, the cats must rest, and dropped the black curtain over the box. After one minute, the curtain was raised again and conmands were given sharply in the following order: "Hands ready." "Ready." "Go." At the word "Ready," the experimenter pressed the button which started the kymograph. We did not time the warning signals, but tried, in each case, to catch the child at the first instant of apparent readiness after the hands were in place.

Reactions were made continuously for one minute, timed with a stop watch. As soon as the minute was over, the experimenter called "Stop. Hands up," stopped the kymograph and let the curtain down over the cats. The child then rested for 60 seconds, without getting down from his stool. Each series consisted of 5 work minutes and 4 rest minutes in the order W—R—W—R etc. As previously stated, one series a day was given for 10 days as nearly consecutive as possible. All of the children, except one who dropped out because of illness, ran through the 10 series.

Instructions were repeated at the beginning of each day's experiment for the first four or five days. One or two of the subjects found it difficult to grasp the idea of the task and, therefore, received special help, on the first day, while the eyes were flashing. After the third day it seemed unnecessary to repeat instructions, so the children were simply given a reminder at the beginning of the first work period on each day following: "You remember what you do, don't you?" During the running of a series, children were not addressed or interrupted unless extreme need arose for encouragement or control.

RESULTS

The subjects were divided into two groups, A and B. Group A consists of the 4 children with whom the experiment was started. These subjects reacted to the initial rate or stimulation (4 flashes per light per minute) throughout all ten of the series. As has been stated, this rate proved too slow to hold the interest of the children after learning was established. The conditions of the experiment were, therefore, altered by doubling the original number of light flashes per minute beginning with Series IV.

This change in procedure made it necessary to discard the first four sets of records. Inspection of these data shows that actual performance was probably not much affected by rate of stimulation within the given range. Curves of efficiency and variability take about the same form for the four "slow" children as they do for the youngsters in the main experimental group. The kymograph reading, however, can give no picture of the difficulty we had in holding these children to their task. The dominant idea, see—light—push—button, was apparently not strong enough to span the relatively long waits between flashes. It seemed to fade about the middle of the interval leaving the youngsters receptive to all sorts of other stimuli,—to which they certainly responded. Every tack in the Cat box, every crack in the floor, every screw in the telegraph keys became astoundingly important, so that only the most extraordinary vigilance on the part of the experimenter kept the apparatus intact and the subjects present either in body or in spirit.

Our experience with Group A made it very clear to us that too little stimulation can be as disintegrating and destructive in a learning situation as too much,—a finding which probably has considerable significance. No other conclusions were drawn from this part of the experiment, which does not enter further into the discussion of results.

Group B consists of the 16 children who performed the experiment according to revised technique. The data obtained from these records have been analyzed statistically with reference to the three main lines of interest suggested in the statement of the general problem. The discussion which follows is based entirely upon the work of this group.

Measurement of attention

The value of the conclusions reached in this part of the study depends upon two things:

1. The validity of the assumption that attention means integration, and
2. The accuracy of the method of scoring devised.

The more carefully we observed the children's behavior the more inclined we were to feel that we had a good working hypothesis. Without exception, the subjects making the most successful adaptation to the experimental situation presented the classic picture of attentive behavior. The body was still, held firmly but not rigidly in a position of readiness. The hands rested lightly on the supports, fingers flexed for the forward thrust, each nicely in line with its key. The eyes were fixed intently on a point midway between the two cats on a

level with the lights. One felt, in the total organism, a complete readiness and a singleness of purpose. The light flashed, was perceived. The child responded instantly, following the pattern which he had set, but calling into play the special set of processes involved in selecting the particular finger to press the proper key.

Any changes in the nature of the response were on the negative side and resulted in a less than perfect performance. Talking, swinging the feet, lifting the hands, twisting the head,—any one of these irrelevant bits of activity meant that a sub-group of processes was truant from the main constellation, and responding to other, more or less unrelated, stimuli.

Obviously, in this experimental situation, a measure of attention would be a graded scale with a maximum score for a perfect response and a series of decreasing values for imperfect responses, errors and omissions.

The method of scoring was not decided upon until after the first few sets of records had been critically

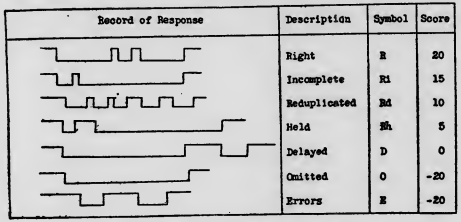

FIG. 1. EVALUATION OF RESPONSES

SERIES I MINUTE A	LIGHTS							
	1		2		3		4	
	Type	Raw Score	Type	Raw Score	Type	Raw Score	Type	Raw Score
Responses	R	20	Rd	10	E	−20	E	−20
	R	20	Rd	10	E	−20	R	20
	Rd	10	Ri	15	Rd	10	Ri	15
	R	20	D	0	R	20	D	0
					Rd	10	Rd	10
					Ri	15		
					E	−20		
Totals.....		70		35		−5		25

FIG. 2. SAMPLE DATA SHEET

studied. This analysis showed that the children were making 7 distinct types of response:

1. Responses entirely correct.
2. Responses which began correctly but were held too long, i.e. after the flash was over.
3. Responses which were incomplete. In these the keys were pressed only part way down, or were pressed and released just as the stimulus light went out.
4. Responses which were correct, but repeated.
5. Delayed responses.
6. Wrong responses.
7. No response at all.

These recorded differences corresponded closely with the observed differences in the attentive behavior of the children. Each less than perfect response meant that the child had failed to be aware of, or to adjust to, one or more significant factors in the total situation,—had failed to this extent to integrate all relevant processes,—to attend.

A numerical equivalent was arbitrarily given to each of these 7 kinds of reaction. For convenience in scoring we adopted a scale with steps of 5, ranging from plus to minus 20. Fig. 1 shows each type of response as it inscribed itself upon the record, together with the symbol used to designate it and the value assigned.

The records were marked on the original kymograph paper and then transferred to data sheets. These data sheets were arranged in such a way that one could see at a glance how many and what sorts of responses were made to each one of the stimulus lights during each one of the working minutes. See fig. 2. By adding the figures in the separate columns, we were able to express numerically the total value of the reactions made to any one of the lights, and thus, by inference, measure the amount of attention which each light received.

Entries on the data sheets were, of course, raw scores, and did not in any way indicate the percentage of rightness of individual responses. Raw scores were, therefore, converted into true (T) scores. These true scores are quotients obtained by dividing the raw score for a given interval by the highest attainable score for the same length of time. To get these perfect scores, we multiplied the actual number of stimulations occurring in the given interval by 20.

Illustration: During Minute A, Series I, the lights flashed 16 times. A perfect response would be worth 16 × 20, or 320 points. Actually the responses were 20 in number,—5 perfect, 3 incomplete, 6 reduplicated, 2 delayed, 4 errors. The total value of these (See fig. 3) is 125. T score for Minute A, Series I, is 125 divided by 320, or .39.

The highest possible T score was 1.00; the lowest possible, an indeterminate minus depending on the amount of deduction for errors.

Basic calculations were made as follows:

1. T scores for each light for: (a) Each working minute, (b) Each series.

2. Mean T scores for: (a) Each light for each minute, (b) All lights for each minute, (c) All lights for each series.

3. Mean variations for : (a) Each light for each minute, (b) All lights for each minute, (c) All lights for each series.

There is a source of error in the scor-

ing which should probably be mentioned here. The same pens on the kymograph recorded both stimulations and responses. The two, therefore, appeared together on the same drawing. In most cases responses were easy to score, and stimulations easy to count. There were instances, however, particularly in cases where the children held the key too long, when the number of stimulations could not be determined with absolute accuracy. Since these instances were comparatively few, since all records were corrected by the same experimenter, and since each record was checked over three times, the results in the opinion of the writer, are not to be seriously questioned on this account.

Control of attention

This phase of the problem was studied from two points of view. We wanted to see whether the children. actually gave increasingly better attention during the course of the experiment. We also wanted to find out whether progress, (if any) could be analyzed in such a way as to show steps in the acquisition of control.

The nature of our experimental situation favored both lines of inquiry. We had, in the first place, a series of responses that could be scored for any given unit of time. Central tendencies, therefore, could easily be ascertained by comparing scores. Secondly, we had a task requiring distribution of attention to a certain known number of discrete stimuli dispersed spatially and temporally in a manner controlled by the experimenter. This meant that the total response pattern could be broken up into single reactions to individual stimuli. One could thus discover, by studying these unit responses, whether attention was evenly distributed over the entire field, or tended to dwell upon parts of the whole. One could also discover, in this way, the relationship (if any) between this factor of distribution and the success of the complete reaction. At the same time one could study the influence upon the total performance of such known conditioning factors as the position of the lights.

We considered first the matter of absolute achievement. A graph was made for each child upon which were plotted consecutively the T scores for each work minute. Each set of 5 dots represented one series. Each curve was interrupted between Series III and IV to mark the point at which the rate of stimulation was accelerated. These first curves were smoothed by drawing over them second curves plotted from the means of the series. See fig. 3. Inspection of these graphs shows that every child improved, to some extent, in his total response to the test situation. This means, on the basis of our definition of attention, that each child improved in his ability to attend to this particular learning situation.

The data were next examined from the standpoint of variability, or relative achievement. The variability in mean T scores from minute to minute was calculated in the usual manner for each series. A third curve was then added to each chart, the plotting points being these mean variations. (Fig. 3.) A low mean variation for a given series meant that T scores for separate minutes in that series were nearly equal;

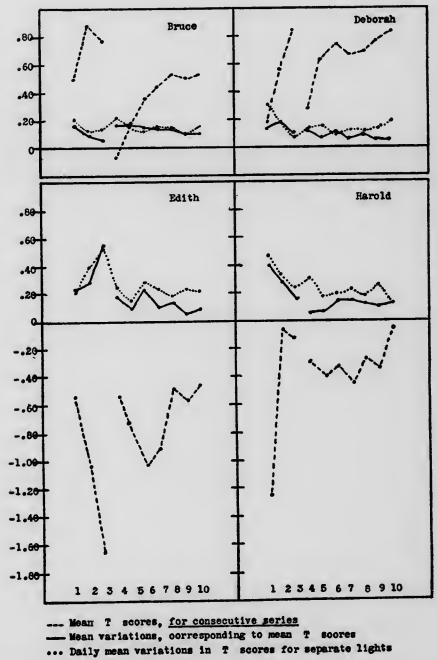

FIG. 3. SAMPLE CHARTS SHOWING PROGRESS IN EFFICIENCY, VARIABILITY AND POWER TO DISTRIBUTE ATTENTION

— — — Mean T Scores for Consecutive Series; —— Mean Variations, Corresponding to Mean T Scores; ..... Daily Mean Variations in T Scores for Separate Lights.

in other words, that performance was fairly even. A high mean variation, on the other hand, meant extreme differences in T scores from minute to minute during the series. Inspection of these variability curves indicated that in every case there was a marked reduction in variability during the progress of the experiment.

Composite curves of efficiency and variability show clearly the rise in the first and the drop in the second for the group as a whole. See fig. 4.

With these general trends in mind we analyzed the data in further detail, considering:

1. The nature of progress in relation to certain key series for both efficiency and variability.

2. Relationships implicit in the data.

3. Unitary responses to individual stimuli (the separate lights). These were studied from the standpoint of: (a) Distribution of attention to the several lights in the field, and (b) The influence of position of stimuli upon the stimulus value of individual lights.

There were, because of the nature of the test situation, 3 critical series in each full set of reactions,—I, IV, and X. These represented the attack, adaptation to the changed rate of stimulation, and the finish. Was X uniformly better than I? Was there a break at IV? Where were the best scores made? What was the range of initial mean scores, final mean scores, best mean scores? What was the range of scores for initial, final and lowest mean variability? At what point was variability reduced to its lowest terms? We made some headway in all of these directions.

TABLE 2

Mean T scores for key series

NAME OF CHILD	SERIES			
	I	IV	X	Best
Ada	−1.95	−.21	.28	.37
Bertha	− .01	−.38	.10	.14
Bruce	.51	−.06	.52	.54
Christine	.42	−.25	.14	.14
Deborah	.19	.28	.83	.83
Dolly	.46	.00	.61	.61
Edith	− .66	−.54	−.47	−.47
Esther	− .60	.20	.27	.42
Harold	−1.25	−.31	−.07	−.07
Jessie	− .73	−.67	−.56	−.56
John	− .98	−.53	−.57	−.41
Laura	− .03	−.38	.40	.42
Martin	−1.66	−.68	−.79	−.68
Peter	− .23	−.45	−.20	−.19
Robert	−1.61	−.91	−.44	−.32
Spencer	− .16	−.35	.53	.53
Range for each series	−1.95 to .51	−.91 to .38	−.79 to .83	−.68 to .83

TABLE 3

Mean variations in T scores for key series

NAME OF CHILD	SERIES			
	I	IV	X	Best
Ada	.46	.09	.05	.05
Bertha	.06	.21	.12	.05
Bruce	.17	.17	.10	.10
Christine	.12	.16	.13	.10
Deborah	.15	.12	.06	.06
Dolly	.19	.15	.15	.15
Edith	.23	.19	.09	.07
Esther	.48	.19	.20	.04
Harold	.41	.06	.12	.06
Jessie	.37	.19	.13	.11
John	.28	.08	.21	.08
Laura	.23	.06	.04	.04
Martin	.38	.19	.11	.09
Peter	.23	.06	.08	.06
Robert	.29	.15	.23	.05
Spencer	.31	.10	.05	.05
Range for each series	.48 to .06	.21 to .06	.23 to .04	.15 to .04

TABLE 4

Best scores for efficiency and variability in relation to the series in which they occur

NAME OF CHILD	EFFICIENCY		VARIABILITY	
	Best score	Series in which this occurs	Best score	Series in which this occurs
Ada	.37	9	.05	10
Bertha	.14	7	.05	9
Bruce	.54	8	.10	10
Christine	.14	10	.10	7
Deborah	.83	10	.06	10
Dolly	.61	10	.15	4
Edith	−.47	10	.07	9
Esther	.42	9	.04	8
Harold	−.07	10	.06	4
Jessie	−.56	10	.11	9
John	−.41	7	.08	4
Laura	.42	7	.04	10
Martin	−.68	4	.09	9
Peter	−.19	8	.06	4
Robert	−.32	9	.05	7
Spencer	.53	10	.05	10

TABLE 5

Distribution of best scores according to series

SERIES	EFFICIENCY		VARIABILITY	
	Number of best scores	Percentage	Number of best scores	Percentage
4	1	.06	4	.25
5	0	.00	0	.00
6	0	.00	0	.00
7	3	.19	2	.13
8	2	.12	1	.06
9	3	.19	4	.25
10	7	.44	5	.31
Totals....	16	1.00	16	1.00

were higher than initial T scores for the same subjects. The rise, however, was by no means regular. Special analysis of the first three series for all records shows that 10 of the curves rose rapidly, 1 remained on a plateau, and 5 went decidedly down.

b. There was a decided break for every child between Series III and IV. This did not mean the same thing in every case, however. Every one of the 10 subjects who gained rapidly for the first three days was set back when the rate was changed. The

TABLE 6

Changes in mean scores for efficiency and variability with change in rate of stimulation

NAME OF CHILD	MEAN T SCORES				MEAN VARIATION			
	Series III	Series IV	Gain	Loss	Series III	Series IV	Gain	Loss
Ada	.45	−.21		1	.18	.09	1	
Bertha	.07	−.38		1	.13	.21		1
Bruce	.78	−.06		1	.07	.17		1
Christine	.25	−.25		1	.19	.16	1	
Deborah	.85	.28		1	.10	.12		1
Dolly	.73	.00		1	.09	.15		1
Edith	−1.65	−.54	1		.55	.19	1	
Esther	.38	.20		1	.17	.19		1
Harold	− .12	−.31		1	.17	.06	1	
Jessie	− .74	−.67	1		.37	.19	1	
John	−1.60	−.53	1		1.12	.08	1	
Laura	.32	−.38		1	.17	.06	1	
Martin	−2.31	−.68	1		.38	.19	1	
Peter	.18	−.45		1	.11	.06	1	
Robert	−2.44	−.91	1		1.22	.15	1	
Spencer	.43	−.35		1	.16	.10	1	
Total number gained or lost			5	11			11	5
Percentage			31%	69%			69%	31%

1. Analysis of the Nature of Progress. (Tables 2 to 6 inclusive.)

The general conclusions which were reached when the data were analyzed from this point of view may be stated as follows:

a. In all instances, final T scores child who had heretofore made no progress, began to gain. Of the 5 children who had been losing ground, 1 continued on down hill, but 4 made significantly better scores on the fourth day than on the third.

c. There were two kinds of high

scores. There was the high mark obtained within the first three series by the child who adapted immediately to the task and took full advantage of the slow rate of stimulation to run up a good score. More important than this was the highest T score obtained on the relatively long stretch between IV and X after the rate of stimulation was doubled. It is this latter which will be regarded as the best score and referred to as such throughout the rest of this paper. These best scores distributed themselves throughout the several series from IV to X, but tended to appear toward the end. Seven, or 44 per cent, of them occurred in Series X. This probably indicates that most of the children were still improving in ability to attend the given situation when the experiment ended.

d. The range of mean scores in each group was fairly wide.

Initial scores ranged from −1.95 to .51
Final scores ranged from − .79 to .83
Best scores ranged from − .68 to .83

TABLE 7

Correlations for each child between efficiency and variability, based on rank order comparisons of daily mean T scores and daily mean variations

NAME OF CHILD	r	P.E.
Ada	.32	±.20
Bertha	.29	±.20
Bruce	.81	±.08
Christine	.15	±.22
Deborah	.64	±.13
Dolly	.21	±.21
Edith	.70	±.11
Esther	.82	±.07
Harold	−.03	±.22
Jessie	.84	±.07
John	.82	±.07
Laura	.47	±.17
Martin	.50	±.17
Peter	.18	±.22
Robert	.71	±.11
Spencer	.38	±.19
Mean	.49 ±.17	
Range	−.03 ±.22 to .84 ±.07	

TABLE 8

Intercorrelations between mean T scores for key series

SERIES COMPARED	r	P.E.
Initial and Final	.64	±.10
Initial and Best	.66	±.10
Best and Final	.98	±.01

TABLE 9

Intercorrelations between mean variability scores for key series

SERIES COMPARED	r	P.E.
Initial and Final	.09	±.18
Initial and Best	−.31	±.16
Best and Final	.39	±.15

The minus scores are chiefly due to omissions and errors. Improvement means reduction of error and increasing accuracy in response.

e. The range in variability of score is as striking as the range in mean scores.

Initial mean variations range from .48 to .06
Final mean variations range from .23 to .04
Lowest mean variations range from .15 to .04

TABLE 10

Intercorrelations between scores for efficiency and variability

MEASURES COMPARED	r	P.E.
Initial mean T score and initial mean variability..	.81	±.06
Final mean T score and final mean variability....	.40	±.15
Highest mean T score and lowest mean variability..	.24	±.17

TABLE 11

Correlations between I.Q.s and mean T scores for key series

MEASURES COMPARED	r	P.E.
I.Q. and initial mean T score.....	.30	±.16
I.Q. and final mean T score..	.60	±.11
I.Q. and best mean T score..	.60	±.11

f. A study of the variability in score from series to series proved particularly interesting. Two children had records showing the lowest mean variation in Series III. In all other cases, the lowest mean variation was attained in a later series. These low variations were found somewhat earlier in the learning than the high scores for efficiency. Four of them are in Series IV, and only 5, or 31 per cent, in Series X. Evidently the steadying down in performance came before the high point in achievement was reached.

2. Study of Relationships Implicit in the Data (tables 7 to 12 inclusive). Certain questions of relationship next arose, suggested by the data already accumulated. Was the child who gave the best performance in the beginning the child who finally achieved the best score, the highest final score? Was the child with the highest I.Q. the child who made the best initial score, the best score, the highest final score? With regard to variability, was the child who showed least variation in the first series the child who showed least at the end? Was there any discoverable connection between initial scores and best, i.e. lowest, scores for variability? What, in general, was the relation between efficiency in total performance and variability? Which is the better basis for predicting how a child of this age will follow through a task,—his I.Q. or the quality of his first attack upon the problem?

TABLE 12

Correlations between I.Q.s and mean variabilities for key series

MEASURES COMPARED	r	P.E.
I.Q. and initial mean variability.....	.12	±.17
I.Q. and final mean variability.....	.09	±.18
I.Q. and lowest mean variability.....	.36	±.15

Because of the small number of cases used in this study, any correlations calculated were bound to have large probable errors. Certain coefficients were worked out by Pearson's rank order method, however,— $r = 1 - \frac{6\Sigma d^2}{N(N^2-1)}$; P.E. $= .7063\ \frac{1-r^2}{\sqrt{N}}$. These measures are gross, but probably accurate enough to show tendencies. The following coefficients of correlation were obtained:

a. The correlation between efficiency of performance and variability for each individual child. In 8, or 50 per cent, of the cases this correlation was. 50 or over; being .80 or above in 4 instances. For at least half of the children, then, the best performances tended to be the most even.

b. Correlations between initial, final and best scores for performance. These show, in general, a tendency for the child who is successful on the first series to be successful throughout. There is a very high correlation, .98 ± .01 between final score and best score, indicating that the last series was usually the best.

c. Correlations between initial, final, and lowest scores for mean variability. These show a negligible amount of coincidence. The child whose approach is erratic may pull himself together and later be quite steady. Correlation between scores for final variability and least variability is low, .39 ± .15, which suggests that the steadying down comes somewhere before the last series.

d. Correlations between group scores for efficiency and variability. These give a high positive correlation, .81 ± .06, between initial efficiency and initial variability, but nothing else significant. Just as, in individual cases, the best series tended to be the most even, so here for the group, the best initial performances tended to show the least variability. As the other correlations would lead one to suppose, there is a very slight relationship between final performance and final variability. One is somewhat at a loss, however, to explain the very low correlation, .24 ± .17, between the very best scores and the lowest variabilities.

e. Correlations between I.Q. and efficiency, and between I.Q. and variability. These would seem to indicate that the I.Q. correlates fairly well with either best or final performances (these correlate with each other), but not appreciably with any of the other measures. A high I.Q. on this age level may be a good reason for expecting ultimate success with this sort of problem, but does not guarantee a good first performance. Conclusions are tentative because of the relative unreliability of these early I.Q.'s.

3. Detailed Analysis of Unitary Responses. The nature of the experimental set-up was peculiarly favorable for this part of the study. Report of the analysis follows:

a. Distribution of attention to disparate stimuli. It will be remembered that adequate response to this test situation involved a distribution of attention to 4 stimulus lights, and that the kymograph recorded the reactions to these separately. On the data sheets these lights were numbered 1, 2, 3, and 4 beginning with the light on the left. As previously explained, the score for each response to each flash was entered on the data sheet under the number corresponding to that light. In the scores for each work minute for each individual position we thus had a numerical measure

of distribution of attention which seemed fairly satisfactory. If light 1 were found to have a consistently higher score than light 3, one would probably be justified in assuming that light 1 received a greater share of attention. If on the other hand, all 4 lights received approximately equal scores, for a given interval, one would assume that atention during that interval was more or less evenly distributed over the whole field.

TABLE 13

Averages of the daily mean variations in scores for distribution of attention to each light for each minute

NAME OF CHILD	SERIES									
	1	2	3	4	5	6	7	8	9	10
Ada	.73	.37	.29	.20	.25	.28	.21	.25	.23	.15
Bertha	.35	.28	.24	.18	.22	.15	.15	.15	.16	.16
Bruce	.19	.13	.14	.22	.16	.12	.16	.15	.10	.16
Christine	.28	.20	.29	.22	.11	.19	.17	.14	.27	.21
Deborah	.30	.18	.07	.14	.15	.09	.12	.11	.13	.19
Dolly	.33	.25	.16	.28	.18	.21	.19	.12	.18	.16
Edith	.21	.39	.52	.24	.15	.28	.23	.18	.23	.22
Esther	.69	.36	.26	.24	.22	.15	.15	.15	.12	.12
Harold	.47	.38	.24	.30	.17	.19	.22	.18	.26	.13
Jessie		.42	.63	.22	.16	.23	.19	.19	.18	.25
John	.43	.49	.47	.18	.39	.27	.24	.32	.40	.39
Laura	.32	.24	.42	.21	.17	.20	.18	.16	.21	.11
Martin	.73	.47	.78	.20	.32	.22	.22	.24	.31	.13
Peter	.29	.34	.29	.13	.16	.16	.20	.21	.12	.18
Robert	.64	.72	1.01	.45	.26	.21	.24	.22	.20	.25
Spencer	.34	.26	.18	.20	.25	.16	.16	.13	.22	.09

In order to obtain a measure of the variability in response to separate lights we proceeded as follows: We calculated the mean score per light per minute, and the mean variation of these scores. We then computed the average of the mean variations for each day. These averages we called coefficients of distribution,—C.D. These averages are the plotting points on charts which represent the "distributability" of each child for each day. (Table 13.) Inspection of these charts shows that in every single case there is a marked difference between the first and last coefficient, which must mean that an original tendency to concentrate on one or two lights alone has been more or less overcome. The curves have the same general shape for all 16 subjects. In 15 of the cases we find a more or less abrupt drop through the first four days to a level upon which the rest of the plotting points fluctuate. Learning apparently takes place fairly rapidly.

Since the first three days of each experiment were days of adjustment for the children, behavior was probably influenced by many extraneous factors which later ceased to operate. At any rate, the raw curves fluctuate extremely during this period. In order, therefore, to be as fair as possible in measuring the difference between initial and final distribution of attention to this problem, we averaged the first coefficients of each series, and the last three for purposes of comparison. Obtaining, for each child, the actual difference and the percentage of difference between these derived coefficients (table 14), we find that (1) The percentage of reduction ranges from 7 per cent to 72 per cent, and that (2) The average drop in variability in score for separate lights is 45 per cent.

TABLE 14

Comparison of initial and final variability in distribution of attention to the four lights. C.D. = coefficient of distribution. See text

NAME OF CHILD	INITIAL C.D.	FINAL C.D.	GAIN	PERCENTAGE OF GAIN
Ada	.46	.21	.25	.54
Bertha	.29	.16	.13	.45
Bruce	.15	.14	.01	.07
Christine	.26	.21	.05	.19
Deborah	.19	.11	.08	.42
Dolly	.25	.15	.10	.40
Edith	.38	.21	.17	.45
Esther	.41	.13	.28	.68
Harold	.35	.19	.16	.45
Jessie*	.53*	.21	.32	.60
John	.46	.37	.09	.20
Laura	.33	.16	.17	.51
Martin	.66	.23	.43	.65
Peter	.30	.17	.13	.43
Robert	.79	.22	.57	.72
Spencer	.26	.15	.11	.42

* Based on 9 Series, (II to X inclusive).

In order to relate this finding to other measures already obtained the following correlations were calculated, the rank order method again being used.

1. The correlation, in the case of each individual child, between measures of distribution of attention and (a) Measures of efficiency, (b) Measures of variability.

These do not give conclusive results. The correlations between efficiency and ability to distribute attention range from .93 ± .03 to −.81 ± .08, average, roughly .49. In 7 of the cases the correlation is .50 or over. (Table 15.)

The correlations between variability in performance and ability to distribute attention range from .90 ± .04 to −.27 ± .21. The average is approximately .74. Here with 8 of the children the correlation is .50 or over. See table 15.

2. Correlations, for the group, between measures of efficiency and distribution of attention. These are all positive, and fairly high, (table 16.)

3. Correlations, for the group, between measures of variability and distribution of attention. Two of these are positive and one not significant (table 17). The correlation between the scores for mean variability on the initial series, and the initial coefficients of distribution is fairly high, .71 ±.09. There is no correlation, for the group, between the scores for lowest variability and most even distribution. This may be because it is possible to give well distributed attention to a total stimulus pattern for one testing minute, and yet be essentially inattentive to the whole situation the next, which would mean a high variability for the series even though the coefficient of distribution were very low.

TABLE 15

Correlations for each child between daily mean variation in distribution of attention and daily mean measures of efficiency and variability

NAME OF CHILD	CORRELATIONS BETWEEN DAILY MEAN T SCORES AND DAILY MEAN VARIATIONS IN DISTRIBUTION OF ATTENTION		CORRELATIONS BETWEEN DAILY MEAN VARIATIONS IN T SCORE AND DAILY MEAN VARIATIONS IN DISTRIBUTION OF ATTENTION	
	r	P.E.	r	P.E.
Ada	.38	±.19	.90	±.04
Bertha	.22	±.21	−.25	±.21
Bruce	.35	±.20	.47	±.17
Christine	−.38	±.19	−.27	±.21
Deborah	.55	±.16	.12	±.22
Dolly	.26	±.21	.44	±.18
Edith	.66	±.13	.67	±.12
Esther	.64	±.13	.60	±.14
Harold	.15	±.22	.43	±.18
Jessie*	.25	±.22	.50	±.16
John	.93	±.03	.90	±.04
Laura	.36	±.19	.51	±.16
Martin	.78	±.09	.45	±.16
Peter	−.81	±.08	.04	±.22
Robert	.83	±.07	.75	±.10
Spencer	.56	±.15	.59	±.15

*Based on 9 Series only, II to X inclusive.

TABLE 16

Correlations between daily mean variations in distribution of attention and mean T score for key series

MEASURES COMPARED	r	P.E.
Initial mean distribution of attention and initial mean T scores	.78	±.13
Final mean distribution of attention and final mean T scores	.54	±.13
Best mean distribution of attention and best mean T scores	.77	±.07

TABLE 17

Correlations between daily mean variations in distribution of attention and mean variations in T scores for key series

MEASURES COMPARED	r	P.E.
Initial mean distribution of attention and initial variability	.71	±.09
Final mean distribution of attention and final variability	.48	±.13
Best mean distribution of attention and lowest variability	.08	±.17

4. Correlations between I.Q. and ability to distribute attention are all low. Here again the significance of the findings is not clear because of the well known unreliability of the I.Q. in these early age ranges, (table 18).

TABLE 18

Correlations between I.Q. and ability to distribute attention

MEASURES COMPARED	r	P.E.
I.Q. and initial mean distribution of attention	.07	±.18
I.Q. and final mean distribution of attention	.05	±.17
I.Q. and best mean distribution of attention	.42	±.14

Evidently it is possible to learn to distribute attention fairly evenly over a number of elements in a given field. It also seems to be true that whatever the I.Q. measures in these particular children does not help them much in learning to adjust well to a complication of stimuli. It would be extremely interesting to know what capacities do facilitate such an adaptation and what limits the extent to which this can be accomplished.

b. Influence of position of stimuli upon attention. In order to determine whether or not the position of any given light influenced its stimulus value, we analyzed the reactions to the various flashes in terms of theoretical probability. Did any particular light tend to receive the highest scores, i.e. the largest number of correct responses? To determine this we ranked each light for each work minute according to excellence of score, rank 1 being the highest score obtained during one work minute by any one light. We then constructed a 16-fold table in which we entered each light once for every response according to rank and number, (table 19). The theoretical probability that any given light will appear in any one of the four ranks is the same for each, since the number of items (responses) is sufficiently large (3328). This theoretical frequency was calculated and entered in the cells, (figures in italics). The comparison with the theoretical fre-

TABLE 19

Contingency table showing the relation between the theoretical and observed frequency with which each light occupied a given rank according to excellence of score. See text

RANK	POSITION OF LIGHT			
	1	2	3	4
1	*208*	*208*	*208*	*208*
	223.5	147.5	222	239
2	*208*	*208*	*208*	*208*
	223	215	198	196
3	*208*	*208*	*208*	*208*
	213	209	218.5	191.5
4	*208*	*208*	*208*	*208*
	172.5	260.5	193.5	205.5

Top figure (italics) in each cell = theoretical frequency. Lower figure = observed frequency.

quency of the actual number of times that the given stimulus light actually occupied a given rank shows that responses to individual lights follow fairly closely a chance distribution. The coefficient of contingency has not been calculated for the entire table since inspection of separate cell contingencies seems to show that the position of the stimulus light does not have a determining influence in directing the attention of these young children in this experimental situation. There is a slight tendency to favor the right, and a somewhat more pronounced tendency for the second light from the left to be neglected.

Individual differences

Throughout the experiment, individual differences in the behavior of the children were striking. In so far as these could be analyzed they seemed to be due to fundamental differences in personality development or to emotional upsets resulting from experiences outside of the laboratory. Previous training in obedience, coöperation and self-control helped far more than a high I.Q. in meeting this new situation. Two children who seemed especially well taught in these respects showed remarkably even distribution of attention on the first testing day although one I.Q. was 83 and the other 145. Another child with an I.Q. of 145 scattered extremely during the first three series and learned very slowly to attend to the total stimulus pattern.

The emotional upsets were profoundly disturbing to the experiment, but in most cases we did not know our children well enough to be sure of the causes. In some instances, however, we knew enough about the home situations to be able to guess at the reasons for a child's disorganization. The ups and downs in all of Christine's curves are a more or less accurate picture of a prolonged excitement over the coming of a new baby. The abrupt rise on her chart, showing very poor control of attention on the eighth day, coincides with the arrival of the infant. Bertha is a child who comes from a home in which there was constant friction between the parents. She was a sensitive child who was rapidly becoming neurotic in her attempt to adjust to the stresses and strains of a chaotic environment. Constant jarring kept the child so stirred that she was never able to make a satisfactory adjustment to the experiment. Harold was a totally undisciplined little boy who ruled his family by temper tantrums. Thwarting in any way demoralized his powers of self-organization and affected the quality of his attention to a marked degree.

One important factor in the handling of these children did not receive adequate consideration. We had no good check on physical condition, and were not able to arrange for one. We, therefore, do not know to what extent possible organic disturbances may have influenced response. It is true that the one child who was obviously ill with a cold during most of his experiment made very satisfactory progress, both in efficiency of total performance and in learning to control distribution of attention.

We were interested to discover that, even with these young children, the intensity of the overt behaviour was

not a reliable indication of the real extent of the emotional disturbance. In one or two instances an erratic record on the kymograph was our first clue to a profound distress of spirit which later expressed itself in bitter tears.

One hesitates to generalize on the basis of so little real evidence, yet it seems clear, from these observations,

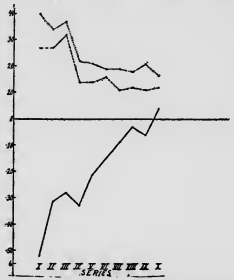

FIG. 4. CHART SHOWING COMPOSITE CURVES FOR EFFICIENCY, VARIABILITY AND POWER TO DISTRIBUTE ATTENTION

..... Mean Scores for Distribution of Attention (Distributability); — — — Mean Variations (Variability); ——— Mean T Scores (Efficiency).

that a condition of emotional stability is essential for the development and control of attention.

SUMMARY AND CONCLUSIONS

In this study of attention in five year old children we have defined attention as integration, or integrated state. On the basis of this definition, we have assumed that one is measuring attention if one measures adequacy of response. We have here attempted to measure such adequacy in a situation involving continuous discriminative reaction to four stimulus lights.

We have found that:

1. All children tested improved in their ability to perform the task required.

2. This improvement was closely accompanied by reduction in variability of performance.

TABLE 20

Recapitulation of mean scores for efficiency, variability, and power to distribute attention

SERIES	MEAN T SCORES	DAILY MEAN VARIATION IN T SCORES	DAILY MEAN VARIATIONS IN DISTRIBUTION OF ATTENTION
1	−.52	.27	.40
2	−.31	.27	.34
3	−.28	.32	.37
4	−.33	.14	.22
5	−.21	.14	.21
6	−.16	.16	.19
7	−.09	.11	.19
8	−.03	.14	.18
9	−.06	.12	.21
10	+.04	.12	.17

3. Both variability and level of final achievement appear to be functions of the ability to distribute attention over a field, an ability which is, in itself, a point of individual difference and subject to modification.

4. There is no evidence that position is a determinant of attention. The picture is, rather, one of original fixation on one or more details (in this case, one of the four positions) with a gradual apprehension and control of all the elements involved.

5. A condition of emotional stability appears to be essential for success-

ful response in all situations requiring concentration of attention.

Fig. 4 (table 20) gives a complete summary of the whole experiment. It shows, in a striking way, the convergence of the three curves representing efficiency, variability and power to distribute attention. One cannot escape the conclusion that the three have a functional relationship.

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